# ADVANCED PRODUCTION, QUALITY & MANUFACTURING

# LESSON PLAN

**Course Number:** PQM 301

**Module & Title:** Lesson No. 1, Lean Design, Manufacturing, QA, and Supply

**Length (total):** 3 Hours

**Terminal Learning Objective:**

**Given the lecture and discussion students will analyze lean design and production principles and practices.** Students will be led through a discussion and analysis of lean design and production techniques used by the auto and aerospace industries. Students will discuss the impacts of lean techniques being applied to the design and production of defense systems.

**Enabling Learning Objectives:**

1. Review the definitions of lean production.

2. Examine the Lean Aerospace Initiative (LAI) and LAI's Lean Enterprise Model.

3. Analyze the characteristics of Lean Design Production principles.

4. Evaluate the impacts of Lean Production on Department of Defense Programs.

**Learning Method:** Lecture/Discussion

**Student Readings:**

**Tutorials - Lean Production / Lean Manufacturing**
**http://www.dsmc.dsm.mil/educdept/mm_dept_resources/tutorials.htm**

**Title:** Teaching Note: Synopsis of "The Machine that changed the World" *(Word Document, size 58KB)*

**Title:** Principles and Overarching Practices from the Lean Enterprise Model (LEM) *(Word Document, size 37KB)*
**Source:** Lean Aerospace Initiative Lean Enterprise Model: Top Level Architecture, July 1998

**Title:** **Learning in a Lean System** (*Word Document, size 36KB)*
**Author:** David S. Veech
**Date:** January 2001

Below articles will be handed out Day One in class

"Building the Lean Machine", Advanced Manufacturing, Jan 2000

" A Lockheed Martin Primer On Lean Manufacturing", Manufacturing News 9 Mar 1999

**Background References:** "The Machine that Changed the World," Womack, Jones & Roos, MacMillan Publishing Co., New York, NY

**Web Sites:** MIT Lean Aerospace Initiative, http://web.mit.edu/lean/

## Conduct of the Lesson:

This lesson is conducted primarily in lecture and discussion format. It is organized into 4 major parts. Section one has the instructor and student developing current perspectives Lean Production. This is accomplished by guided discussion. Section two has the students examining the Lean Aerospace Initiatives Lean Enterprise Model and LAI accomplishments. In section three students analyze the characteristics of Lean Design Production principles. Section four is an update and evaluation the impacts of Lean Production on Department of Defense Programs.

**DEFENSE SYSTEMS MANAGEMENT COLLEGE**
MANUFACTURING MANAGEMENT DEPARTMENT

TEACHING NOTE
**George Noyes, 1997**

The Machine that Changed the World (Synopsis)

This book was written by the three senior managers of the International Motor Vehicle Program. It was a program born out of an international conference to announce publication of their previous book, The Future of the Automobile, in which they examined the problems facing the world motor-vehicle industry in 1984.

The authors concluded that the auto industries of North America and Western Europe were relying on techniques that had changed very little from Henry Ford's original mass production system and that those techniques were simply not competitive with the new set of ideas pioneered by Japanese companies.

These three men decided the most constructive step they could take would be to undertake a detailed study of the new Japanese techniques, which they subsequently named "lean production", compared with older Western mass production techniques. In order to do this, they developed the International Motor Vehicle Program (IMVP) operating out of the new Center for Technology, Policy and Industrial Development at Massachusetts Institute of Technology (1985). The charter of the center was to go beyond conventional research to explore creative mechanisms for industry-government-university interaction on an international basis in order to understand the fundamental forces of industrial change and improve the policy-making process in dealing with change.

In studying the lean production process, the IMVP realized their success depended critically on thoroughness, expertise, a global outlook, independence, industry access and continuous feedback. They felt they had to examine the entire set of tasks necessary to manufacture a car or truck: market assessment, product design, detailed engineering, coordination of the supply chain, operation of individual factories, and sales and service of the finished product. This research was conducted by an international team of researchers in academia, but who had come from the world of industry from Japan, Europe, and America. They also included studies of supply systems in leading developing countries, including Korea, Taiwan and Mexico.

Funding for the $5 million project came from contributions from many car companies, components suppliers, and governments. Contributions from individual companies and governments were limited to 5% of the $5 million total, thereby eliminating national or regional pressures in the conclusions that were ultimately drawn.

IMVP was given extensive access to motor vehicle companies across the world, from the factory floor to the executive suite. They were amazed by the spirit of professionalism that was exhibited by the entire industry and which moved managers in the worst facilities and weakest companies to share their problems frankly, and managers in the best plants and strongest companies to explain their secrets candidly.

This book is the conclusion drawn, not by the entire program, but by the three directors of it who have now spent five years exploring the differences between mass production and lean production in one enormous industry. They feel their story is not just for an industry audience, but for everyone; government officials, labor leaders, industry executives and general readers, in every country with an interest in how society goes about making things.

The best way to describe lean production is to contrast it to its predecessors: craft production and mass production. Craft production uses highly skilled workers and simple but flexible tools to make exactly what the consumer asks for, one item at a time. The result is that consumers get exactly what they want but at a prohibitively high cost. Mass production uses narrowly skilled professionals to design products made by unskilled or semiskilled workers tending expensive, single-purpose machines. The machines produce standardized products in very high volume. Due to the high cost of disruption of the process, the mass producer adds many buffers - extra supplies, workers and space - to assure smooth production. Also due to high cost of changing over to a new product, the mass producer keeps standard designs in production as long as possible. The result is the consumer gets lower costs but at the expense of variety, and workers tend to find their part of the process boring.

Lean production, by contrast, uses teams of multiskilled workers at all levels of the organization, and uses highly flexible, increasingly automated machines to produce large volumes of products in enormous variety. The term "lean" comes from its using half the human effort in the factory, half the manufacturing space, half the investment in tools, and half the engineering hours to develop a new product in half the time.

The most striking difference though between mass and lean production is that mass producers set a goal for themselves - "good enough." To do better would cost too much or exceed inherent human capacities. The lean producer, on the other hand, sets his sights on perfection, thereby delivering ever-increasing benefits. Lean production also pushes responsibility farther down the organizational ladder, to individual workers.

Lean production also calls for individuals to learn a vast number of professional skills and apply these creatively in a team setting. This contrasts with the traditional ideas of career pathing, where an individual develops higher levels of technical knowledge and proficiency in an ever-narrowing area of specialization. The paradox is that the better you are at teamwork, the less you may know about a specific, narrow specialty.

## The Origin of Lean Production

Henry Ford created the Model T in 1908 - his 20th design over a five-year period. He had, in the Model T, finally met two objectives: a car that was designed for manufacture and was user-friendly (almost anyone could drive and repair the car without a chauffeur or mechanic). The key to mass production wasn't the continuously moving assembly line, as many people believe, but rather the complete and consistent interchangeability of parts and the simplicity of attaching them to each other.

In craft production, each piece was created by an individual craftsman, the majority of whom were independent contractors with a manufacturing organization. Each craftsman used his own gauging system in manufacturing his part. Once parts were created, the first piece and the second piece were put together with filing and adjustments made until they fit perfectly. Then the third piece was added and adjusted accordingly, and so on, until an entire automobile was assembled. The biggest problem was that each piece was made using a different gauge and then fired for hardness. This usually warped the metal and the piece had to be machined again to regain its original shape. The end result was usually a mere approximation of the original dimensions.

To achieve interchangeability, Ford insisted that the same gauging system be used for every part all the way through the entire manufacturing process. Ford also benefited from the recent development of pre-hardened metals. Taken together – interchange-ability, simplicity, and ease of attachment - Ford was able to eliminate the skilled fitters who had always formed the bulk of every assembler’s labor force, as just one advantage over competition.

In 1913, Ford introduced the first moving assembly line in the Highland Park plant in Detroit. Rather than individual workers creating one whole automobile before beginning another one, he had honed the concept of the worker remaining in one spot and the product, components and tools would come to the worker. This created the concept of the unskilled worker who no longer needed to understand the whole production process but merely needed to be able to attach two screws to two nuts or put one wheel on every car that came by all day long. He had not only created the interchangeable part, but the interchangeable worker as well.

By 1915, Ford had further streamlined the process to include the vertical integration of supplies. Rather than buying his chassis and engines from the Dodge brothers (as he had been doing) and a host of other products from other firms, he brought all these functions in-house. The decision was made partly because Ford had perfected mass-production techniques before his suppliers and could achieve substantial cost savings by doing everything himself. He also trusted no one but himself. Lastly, he needed parts with closer tolerances and on tighter delivery schedules than anyone had previously imagined. So he decided to replace the mechanism of the market with the "visible hand" of organizational coordination.

By the early 1920s, General Motors was also in the running as a mass producer of automobiles. Unfortunately, its founder, William Durant, was a classic empire-building man; he had no idea how to manage anything once he bought it. He was ousted from management by his bankers in 1920, and replaced by Alfred Sloan. In order to manage the five major companies owned by General Motors, Sloan developed the principal of managing objectively "by the numbers." Sloan and the other senior executives oversaw each of the company’s profit centers by evaluating detailed sales, market share, inventory, and profit and loss reports. Sloan felt it unnecessary for executives to understand the details of operating each division. The numbers would show performance; if performance was down, it was time to change the general manager, if it was good, the manager was a candidate for promotion to the vice-presidential level.

Sloan used the same decentralized management theories across the entire company; domestically and internationally, as well as across disciplines. He essentially developed the last part of the division of labor that Ford had begun. Ford had developed the rework specialist and general foreman of the assembly line, to manage the errors of the interchangeable worker, and the engineers to design the product and processes. Sloan added the financial manager and marketing specialist to control the rest of the corporate structure. This was the completion of the entire mass production process.

While mass production was being perfected in the US, it was also beginning to flourish in Western Europe. In the late 1950s, VW, Renault and Fiat were producing at a scale comparable to Detroit's major facilities. A number of the European craft production firms also made the transition to mass production.

By the 1970s, the Europeans were specializing in cars very different from Americans though. They were offering compact, economy cars, such as the VW Beetle, and sporty, fun-to-drive cars, such as the MG. They were also developing new product features including front wheel drive, disc brakes, fuel injection, unitized bodies, five-speed transmissions, and engines with high power-to-weight ratios. Unfortunately, their production systems were nothing more than copies of Detroit's but with less efficiency and accuracy.

In the spring of 1950 a young Japanese engineer, Eiji Toyoda, set out on a three month pilgrimage to Ford's Rouge plant in Detroit (Ford invited large numbers of engineers from around the world to visit his plant; he kept no secrets about mass production). The Rouge plant was the largest, and most complex in the Ford family, if not the world. After much study, he went back to Japan and with the help of his production genius, Taiichi Ohno, they soon concluded that mass production would never work in Japan. From this tentative beginning was born what Toyota came to call the Toyota Production System, and ultimately "lean production."

Toyota faced a host of problems in Japan. Their domestic market was tiny and demanded a wide range of vehicles from luxury cars for executives, to large and small trucks for farmers and factories, and small cars for the crowded cities and high energy prices. The native Japanese work force also was no longer willing to be treated as a variable cost or as interchangeable parts. Japan also did not have the advantage of "guest workers" (that is temporary immigrants willing to put up with substandard working conditions in return for high pay) such as had been available in America and in Europe.

The first process that Ohno tackled was stamping of sheet metal. Until now, the standard practice had been to stamp a million or more of a given part in a year. Unfortunately, Toyota's entire production was to be a few thousand vehicles per year. Ohno concluded that rather than dedicating a whole set of presses to a specific part and stamping these parts for months or even years without changing dies, he would develop simple die change techniques, and change dies frequently (every two to three hours, versus two to three months) using rollers to move dies in and out of position. This way he would need only a few presses rather than a large number of them, and he found it was actually cheaper to produce a smaller number of parts and not have to inventory them.

Not only did he save on the cost of inventory, but mistakes were also caught much earlier in the process. He also hit upon the idea of letting the production workers themselves perform the die changes instead of needing specialists to perform these tasks.

Lean production - company as community

Ohno realized though, that in order to achieve success in his new process, workers would need to be motivated to look for and correct mistakes and to be extremely skilled in their work at the same time. If workers failed to anticipate problems before they occurred, and didn't take the initiative to devise solutions, the work of the factory would come to a halt.

As it happened, his work force acted to solve this problem for him in the late 1940s. Due to problems with the Japanese economy, Toyota was facing a deep slump in business. The company was looking at firing one quarter of the work force. However, the company's union was in a strong position and chose to strike. The result of the negotiations was that the company and the union worked out a compromise that today remains the formula for the labor relations in the Japanese auto industry. One quarter of the work force was let go, but the remaining employees received two guarantees. One was for lifetime employment. The other was for pay steeply graded by seniority rather than by specific job function, and tied to company profitability through bonus payments. Toyota was promising lifetime employment, but in return they were expecting that most employees would remain with Toyota for their working lives. This was a reasonable expectation, because by leaving companies and starting over again, a worker would lose his seniority.

Workers also agreed to be flexible in work assignments and to be active in promoting the interests of the company by initiating improvements rather than merely responding to problems. In effect, the company officials felt that if they were going to take on an employee for life, the employee would have to do his part by doing the jobs that needed to be done.

Lean production - assembly plant

Ohno then went on to rethink the assembly process. He chose to regroup the assembly workers into teams. Where Ford had given the jobs of housekeeping, tool repair and quality checking to independent specialists, Ohno gave these responsibilities to each team. Where Ford had felt that it would be better to let a mistake go through to the end and have a rework specialist correct an error, Ohno felt that rework was merely a costly addition that was unnecessary. Instead, Ohno placed a cord above every workstation and instructed workers to stop the whole assembly line immediately if a problem emerged that they couldn't fix. Then the whole team would come over to work on the problem.

He also instituted a system of problem solving called "the five why's." Workers were taught to trace every error back to its ultimate cause, then to devise a fix so that it would never occur again. By the time Ohno's system hit its stride, the amount of rework needing to be done was minimal. Workers were able to catch almost every error as it occurred. The quality of cars shipped also steadily improved. This was because quality inspection, no matter how diligent, simply cannot detect all the defects that can be built into today’s complex vehicles.

Today, Toyota's assembly plants have almost no rework areas. By contrast, the number of current day mass production plants devote 20% of plant area and 25% of their total hours of effort into fixing mistakes.

<u>Lean production - supply chain</u>

The next part of the process that Ohno tackled was the supply chain. Where mass producers typically sought bids on a given number of parts from outside firms and internal divisions, the lowest bidder usually got the business. A bidding firm typically was given drawings and told to quote on a given number of part of a given quality. Supplier organizations working to blueprint had little opportunity or incentive to suggest improvements in the production design. Usually, suppliers were given little to no information about the rest of the vehicle, and therefore could not really offer suggestions for improvement, whether based on their own ideas, designs or previous experience.

Ohno also felt there was a problem coordinating the flow of parts within the supply system on a day-to-day basis. The result was high inventory cost, and routine production of thousands of parts that were later found to be defective when installed, based on the fact that they were stamped repeatedly in large quantities without being checked until they got to the factory weeks or months later.

Ohno chose a totally different approach. He gave a potential supplier performance specifications; for example, he told a potential supplier to design a set of brakes that could stop a 2,200 lb. car from 60 miles per hour in 20 feet, ten times in succession without fading. The brakes would have to fit into a space 6' x 8' x 10' at the end of each axle and be delivered to the assembly plant for $40 a set. This system would also have to work in harmony with the other systems of the car. Toyota didn't tell a supplier what they were to be made of or how they were to work. Those engineering decisions were for the supplier to make. In this way, suppliers were able to help improve the design process.

These suppliers were called first-tier suppliers. They were then responsible for establishing second-tier suppliers under themselves. These were the companies that were assigned the job of fabricating the individual parts. While Toyota did not wish to vertically segregate its suppliers into a large bureaucracy, it also did not wish to deintegrate them into completely independent companies. Therefore, Toyota spun off its in-house supply operations into quasi-independent first-tier supplier companies, in which Toyota retained a fraction of the ownership and developed similar relationships with outside suppliers who had been independent. Toyota still holds a percentage of ownership in a number of its former in-house supplier companies. Because Toyota does not own them wholly, these firms have substantial cross-holdings in each other and they also provide supplies to companies other than Toyota and to firms in other industries. At the same time, these companies are intimately involved in Toyota's product development and accept Toyota people into their personnel systems. In a very real sense, they share their destinies with Toyota.

Finally, Ohno developed a new way to coordinate the flow of parts within the supply system on a day-to-day basis, the famous just-in-time system. It was a simple idea, but very difficult to implement because it practically eliminates all inventories. When one small part of a vast production system fails, the whole system can come to a stop. It also removes all safety nets and focuses every member of the vast production process on anticipating problems before they become serious enough to stop everything.

Lean production and engineering

Where mass producers have tried to solve the problem of engineering a manufactured object as complex as today's motor vehicle by finely dividing labor among many engineers with specific specialties, Ohno realized that this system had a great number of weaknesses. Ohno by contrast decided early on that product engineering inherently encompassed both process and industrial engineering. Therefore, he formed teams with strong leaders that contained relevant experience in both the manufacturing of a product and the engineering of design. Career paths were restructured for engineers so that rewards went to strong team players, rather than to those displaying genius in a single area of product, process, or industrial engineering.

Lean production and changing consumer demand

By the 1980s, reliability was one of the strongest factors in car purchases. Toyota's lean production system delivered superior reliability. Toyota found it no longer had to match the price of competing mass production products. Toyota's flexible production system and its ability to reduce production engineering costs allowed the company to supply the product variety that buyers wanted, with little cost penalty.

By 1990, Toyota was offering consumers around the world as many products as GM, even though Toyota was still half the size. To change production and reengineer a new car at GM costs a fortune and takes many years. Toyota can offer twice as many vehicles within the same development budget. As recently as 1987, a manufacturing manager in Detroit stated that the secret to Japanese success was that they are making identical "tin cans." If he did that, he could have high quality and low cost, too. He didn't realize that the Japanese have a very broad portfolio of products, and have reengineered the entire design and production process to produce high variety at a low cost.

Lean production: dealing with the consumer

Lean production means nothing if the producer cannot build what the customer wants. Henry Ford's link to the consumer was simple; there was no product variety and repairs could be handled by the owner, so the job of the dealer was simply to have enough cars and spare parts in stock to supply expected demand. Unfortunately, the assembler used the dealer as a "shock absorber" to cushion the factory from the need to increase or reduce production. This caused strains between the relationship between the dealer and the customer, and the dealer and the factory. Ohno confronted this problem in the same way as the supplier group. He specifically developed the Toyota Sales Company, which was a network of distributors, some wholly owned, and some in which Toyota held a small equity stake. The dealer became the first step in the production system.

Toyota eventually stopped building cars in advance and converted to a build to order system. Dealers helped in sequencing orders by making house calls. They worked more hours when demand dropped and concentrated on households likely to want the cars the factory could build. They especially focused on repeat buyers. Brand loyalty became a salient feature in Toyota's system.

### ***The Elements of Lean Production***

<u>The lean factory</u>
Surprisingly, the studies of the IMVP have shown that when comparing the worst American automobile plants to the Japanese or European plants, they don't fare nearly as badly as would have been thought. In 1989, the GM plant in Framingham, MA, which rated the lowest in productivity, still ranked higher than the average European owned plant (the Framingham plant closed in 1989.) European plants have now shown to be the home of classic mass production. North American plants have in turn shown that they are adopting many lean production techniques and there are many Japanese transplants in North America that are showing average performance to be similar to that of the average Japanese plant in terms of quality, but lagging by 25% in terms of productivity. The differences are due to different methods of obtaining supplies that necessitate extra work and longer distances. These plants are also still at an early point in the learning curve with respect to lean production. There also is an issue of management; the best performing companies in Japan run the best performing transplants in North America.

We can no longer equate "Japanese" with "lean production" and "Western" with "mass production." The numbers show that lean production can be practiced far away from Japan.

The comparison of automation versus productivity resisted the commonly held beliefs that automation equals productivity. While automation certainly means less effort, is does not necessarily equate into more productivity. Once again, it became a question of manufacturing or designing lean production into the process, before automation is applied.

Two organization features of a truly lean plant are transferring the maximum number of tasks and responsibilities to those workers actually adding value to the car on the line and having in place a system for detecting defects and that quickly traces every problem, once discovered, to its ultimate cause. This means teamwork among line workers. Toyota has in place a simple but comprehensive information system that makes it possible for everyone in the plant to respond quickly to problems and understand the plant's overall situation. In the most advanced lean production plant, information is displayed daily regarding production targets, equipment break-downs, personnel shortages, overtime requirements and so forth. Whenever anything goes wrong, any employee who knows how to help runs to lend a hand. In the end, it is the dynamic work team that emerges as the heart of the lean factory.

Workers need to be taught a wide variety of skills. They need to be cross-trained in their work group so that they can fill in for each other. They all need the additional skills of simple machine repair, quality checking, housekeeping and materials ordering. They need to be taught to think proactively, so they can devise solutions before problems become serious. This is not the same as merely changing the organization chart to show teams and introducing quality circles.

Opponents feel that lean production is no more fulfilling than mass production. They feel that the stress of constantly looking to eliminate the "slack" forces managers to feel they continually have to identify the slack, and assemblers feel that they are constantly at risk of losing their job. The second critique is of lack of fulfillment, and has been combated with "neocraftsmanship." Neocraftsmanship places larger teams of approximately ten workers together, to create one entire vehicle. This process takes much longer than even mass production. There is a difference between the tension of continually improving the process and the challenge of neocraftsmanship. A properly organized lean production system does remove all slack - that’s why it's lean. But it also provides workers with the skills they need to control their work environment and the continuing challenge of making the work go more smoothly. There is a creative tension for the workers to address challenges, but on the other hand management must offer its full support to make this system work. In automotive market slumps, the company must make sacrifices to ensure job security, because it has promised lifelong employment to workers.

Lean design

The fundamental differences in lean design versus mass production design include leadership, teamwork, communication and simultaneous development. Taken together, these four areas make it possible to do a better job faster and with less effort.

Lean producers invariably employ some variant of the Large Product Leader (LPL), pioneered by Toyota. The idea is that the LPL is the boss, whose job it is to design and engineer the new product and get it fully into production. This person carries great power and is perhaps the most coveted position in the company. The difference between this mentality and MP, is that in lean production the team leader is the manager with much power. In a mass production system, the leader is more properly termed a coordinator, whose job it is to convince team members to cooperate.

In lean production, there is the element of the tightly knit team. Engineers are assigned to a project for its life, and come from all the functional areas of the company; market assessment, product planning, styling, advanced engineering, detail engineering, production engineering and factory operations. They retain their ties to their functional area, but for the life of the program they are clearly under the control of the LPL. In the mass production system, engineers are loaned to the coordinator, while continuing to be accountable to their normal department manager. Unfortunately, their department is not usually interested in one project, but on the rest of their responsibilities overall.

Communication is much easier within the lean production system, because the team is headquartered in one place. In mass production, the project usually moves from department to department along the process, with team members staying in their own functional areas, therefore being separated from the project. As conflicts or problems occur, they are not usually communicated to the rest the team. There is also a much smaller number of people involved in a lean production team; 485 versus about 900 in a mass production system. The lean production team also agrees at the beginning what exactly everyone's roles and responsibilities are, and signs individual contracts to that effect. Conflicts regarding resources and priorities occur at the beginning rather than midway through or at the end of the project. In the mass production process, no one agrees to anything in the beginning, and at the end, as problems get bigger and bigger, then the disputes begin. Therefore, it takes many more people to correct the problems.

The last element is simultaneous development. In the traditional process, die making does not begin until after product designers give precise specifications. Then steel is ordered, and cut, going through many processes, usually taking approximately two years to complete. In the lean production process, die designers know the approximate size of the new car and the approximate number of panels in advance, because they have been in communication with the rest of the team all along. They order blocks of steel and make rough cuts early on, getting ready for the final design dimensions. While others are still working on the exact specifications, they are beginning and preparing. The process takes about half as much time as does the traditional process.

The last step of the project is actual production. Western analysts have been mistaken or misled by slow start-up schedules of Japanese transplants to North America. They see them as beginning slowly, therefore meaning slow development. What they don't realize is that by ensuring a slow start-up schedule, a new lean production plant can fully master the Toyota Production System. Therefore they stop as necessary to get each step correct, rather than rushing ahead and going back later to rework not just errors, but the entire production process. Once lean production is fully in place in the factory, it is easy to introduce new products developed by the lean production process.

What does this ultimately mean? Japanese producers are tending to replace models of cars every four years. American mass production companies by contrast are keeping the average model in production for nearly 10 years, because they simply are so inefficient in the product development process. They are finding they do not have the money or engineers to expand their product range or renew their products frequently.

<u>The lean supply chain</u>

In mass production, the supply chain is price driven. The end cost of a vehicle is calculated by supply cost plus profit. A mass assembler will develop detailed drawings of components and put the parts out for bid. Suppliers tend to bid below cost in order to get the original contract, usually for only one year, with the understanding that once they are in place, it is highly unlikely that the assembler will drop their contract for someone else the second year into production. With the life of a vehicle being approximately 10 years, and with 10 more years of life in replacement parts, the supplier is quite willingly to take a loss the first year, with the promise of profits for the following 19 years, due to being able to raise prices every year. Assemblers are not even likely to balk at price increases over the years, because it is cheaper than finding a new supplier.

There are even additional profits to be made in the increased productivity a supplier will develop over the life of a component. As the learning curve increases, the cost of production decreases, adding to a supplier’s profits.

The mass production chain also tends to include many more components for manufacture. Instead of contracting with one firm to make a whole seat, a mass assembler will contract with 25 different companies to make the 25 different components of a seat. Unfortunately, due to different contents of materials, etc. the parts never fit together exactly, or expand the same in hot and cold weather, thereby creating gaps, leaks and squeaks over the life of the car.

In the lean production supply chain, first tier suppliers are established over time, and long standing relationships are set with them. The design team for the assembler will assign whole components (i.e. seats, fuel injection systems) to one first tier supplier. There is no competition amongst suppliers based on bidding. The supplier has its own engineers that then work with engineers from the assembler’s product design team to create a whole component system that works in harmony with the rest of the vehicle design. The first tier supplier then contracts second, third and even fourth tier suppliers to make the components and assemble them.

The lean assembler also establishes a target price for the vehicle from the beginning and works backwards figuring how the vehicle can be made for that price, while still allowing reasonable profit for both the assembler and the supplier. Where the mass production process creates tension between suppliers and assembler as to who can actually make any profit, the lean production system encourages them to work together to allow profit for both companies.

The lean production system also uses the just-in-time method of supply. Where mass production is at the mercy of highly cyclical production and relies on layoffs to manage the cycle in slow periods and large supplier inventory to handle it in swells, the just-in-time method relies on empty parts boxes from the plant being returned to the supplier as the indicator of how many components to supply. The supplier tailors their manufacturing rate to that of the assembler, and makes products in small batches (due to the ease of change in machinery to make different parts), and can therefore manage product flow better than the large continuous batches that are made for years at a time in traditional mass production facilities.

The issue of quality of parts is addressed very differently also. In mass production, parts are inspected as they arrive at the assembly plant. Defective parts are thrown away or returned for credit. When the number of defective parts in a batch becomes too high, the entire batch is returned. In lean production, parts are not inspected at all when they arrive at the plant. They go right to the line. The lean supplier knows what defects can do - they will shut down the whole line - and therefore takes great pains not to let that happen. Again, it is an issue of working together as a team instead of working against each other, competing for profits. When defects are found, the assembler’s quality control department rapidly goes through the "five why’s" to determine the cause of the defect and to address the issue so that it never happens again. This information is shared with the supplier and the problem is corrected together, with the assembler’s assistance if necessary.

The last major feature of lean supply is the supplier associations. Where mass suppliers compete against each other on price, and hold all information regarding price, profit and design as confidential and secret, lean suppliers meet regularly to share information about new ways they have discovered to make better parts. They understand that success for one supplier means success for the rest of them.

***Conclusion***

Lean production raises the threshold of acceptable quality to a level that mass production cannot easily match. It offers ever-expanding product variety and rapid responses to changing consumer tastes. It lowers the amount of high-wage effort needed to produce a product, and it keeps reducing it through continuous incremental improvement.

**LEAN ENTERPRISE MODEL**

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**Responsiveness to Change and Waste Minimization**

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- Right thing at right place, right time, right quantity
- Effective relationships within the value stream

- Optimal quality with first unit production
- Continuous Improvement

# ***LEM PRACTICES***

## 1. IDENTIFY AND OPTIMIZE ENTERPRISE FLOW

*"Optimize the flow of products and services, either affecting or within the process, from concept design through point of use."*

**METRICS**

-- Flow Efficiency = $\dfrac{\text{actual work time}}{\text{total flow time}}$

-- Throughput

-- Order to point of use delivery cycle time

-- Total product development cycle time, concept to launch

**ENABLING PRACTICES**

- Establish models and/or simulations to permit understanding and evaluation of the flow process
- Reduce the number of flow paths
- Minimize inventory through all tiers of the value chain
- Reduce setup times
- Implement process owner inspection throughout the value chain
- Strive for single piece flow
- Minimize space utilized and distance traveled by personnel and material
- Synchronize production and delivery throughout the value chain

- Maintain equipment to minimize unplanned stoppages

# “Learning in a Lean System”

**By**

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**Major, U.S. Air Force**

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ABOUT THE WRITER (Current as of 30 April 2001):

At the time of this writing in January 2001, David Veech was serving as a Professor of Production and Quality Management, at the Air Force Institute of Technology. He supported the Defense Acquisition University by teaching Intermediate Production, Quality, and Manufacturing to members of the Defense Acquisition Workforce. His primary research focus was on Lean Enterprise, collaborating with the Lean Aerospace Initiative's Knowledge Deployment Team to produce learning products such as the Lean Implementation Fieldbook and the Lean Learning Workshop. He had recently completed the Lean Manufacturing Certification Program at the University of Kentucky. He had taught lean principles and practices to several large and small businesses as well as to the Joint Directors of Manufacturing Technology Programs for the Department of Defense. He was the Chairman of the Dayton Ohio Section of the American Society for Quality. Mr. Veech is now with the Center of Robotics and Manufacturing Systems at the University of Kentucky, where he teaches Lean principles and practices in Lean Manufacturing Certification Program.

## **“Learning in a Lean System”**

Throughout history, people have struggled to produce goods in the most efficient way possible. Technology has helped us through two industrial revolutions and our current information revolution. We’re able to do things now that we never dreamed of, yet we still struggle to achieve what we believe to be possible. Right now in hundreds of companies across the country, teams of people are seeking breakthroughs in process improvement to take them to the next level of efficiency. Lean “champions” are busy planning their next Kaizen event. “Blackbelts” and “greenbelts” are busy analyzing their Six Sigma projects. Others are simply chasing the next problem, trying their best to maintain some degree of competitive advantage through brute force.

“Lean” is the term featured in the subtitle of the 1990 book *“The Machine That Changed the World: The Story of Lean Production.”* This book describes the Toyota Production System (TPS) and identifies it as the most efficient manufacturing system in the worldwide automobile industry. One would think that after ten years of studying the elements of the Toyota Production System, manufacturers would have its secrets figured out. But still they struggle, leaping from initiative to initiative and program to program seeking the elusive prey…fewer defects, lower cycle times, lower costs (better, faster, cheaper.) I would like to share some ideas with those going through this “Program of the Month” syndrome (epidemic?) These ideas are based on observation, study, and discussion with a number of people. These ideas are not new; they have been tried and in many cases abandoned; but maybe it's time to re-examine them, this time with a new focus.

To gain a more complete understanding of TPS or lean, consider it a system, rather than a program. It permeates entire organizations, not just the manufacturing operations. Lean is independent of the product or service provided to customers. A lean system doesn't focus on making conforming parts, components, or subassemblies. It doesn't try to compute the number of defective parts. It doesn't focus on the levels of inventory, or when the material is delivered to workstations. It isn't about kanbans, Just-in-Time, or value streams.

Lean is about people, and a lean system focuses on producing quality people. The work the system requires, whether manufacturing, accounting, or engineering, is designed to allow people to learn, to improve, and to succeed. The system itself is essentially invisible to the team members since it requires no special activity to perform its developmental function. Since the team members in a lean system don't "do" lean, they won't suffer through the constantly changing cycles of programs coming and going.

Virtually every aspect of the TPS has been studied, duplicated, and taught by consultants for years. This includes the concepts of employee, stability brought on by Statistical Process Control, Just-In-Time, Jidoka, Heijunka, Poka-yoke, and a dozen other sub-bullets on a speaker's PowerPoint slide. Why then hasn't everyone reached the levels of efficiency Toyota has? What are we missing? I believe that we have had a problem focusing on the right thing.

For years, we have focused on the obvious output, the car, and not necessarily on the carmaker. But if we take a closer look at TPS, we'll see that everything is designed not only to produce a high-quality car, but also to produce a high-quality person. They know how to help their people learn. That's not the same as knowing how to teach. To help illustrate this point, let's take a quick look at learning.

In 1956, Benjamin S. Bloom and others compiled *"Taxonomy of Educational Objectives: The Classification of Educational Goals"* which identified six levels of cognitive learning for people. This is more succinctly refered to as Bloom's Taxonomy. The first three levels - Knowledge, Comprehension, and Application - are where most of us spend the bulk of our adult lives.

We do okay watching "Who Wants to be a Millionaire" and "Jeopardy" because our school and college years introduce us to a lot of varied information. We store that information in various parts of our brains that somehow bring what we want to the surface for us just when the poor guy on TV draws a blank. That's basically the knowledge level. We can recall facts.

Comprehension involves a little more. Here, we actually have to interpret some type of data set and draw some conclusions. We actually understand what that diagram or chart means, or what impact a dip in the market will have on our retirement account. We can tell others what things mean in our own words.

The application level is where we take our knowledge and understanding and use them at work to do our job. That's usually enough for most folks. If I'm assembling a new car, all I really need to know is how to take the parts in my bin and the tools in my workstation and fit them together and fasten them somehow, right? Not really, and you may even agree with me, but that is all most companies will give to their employees. They teach them how to do the job they were hired for, and little else.

The three higher levels of learning are Analysis, Synthesis, and Evaluation. These are the problem solving levels. At these levels, we are able to take chunks of information from various sources, break them down into meaningful parts, recognizing the relationships of those parts to each other. Then we can rearrange the parts, and reassemble them into something different, or identify the piece that's slightly more or less valuable so we can then make a decision and act on it.

The key pieces of the Toyota Production System are those that help team members solve problems as they encounter them on the assembly line. Everything is designed to help those workers reach those higher levels of learning.

If we examine a typical day at Toyota Motor Manufacturing Kentucky (TMMK), every time one of the 7,800 team members pulls the line-stop (or andon) cord, they've identified a problem. That happens somewhere between 10,000 and 15,000 times a day. Every problem needs to be solved. Who better to solve it than the discoverer? If the same problem occurs frequently, maybe there is something wrong with the process. Who better to solve problems with the process than those working it 8 to 10 hours a day? The only problem with getting our line employees involved in solving problems is that we haven't taken the time to teach them how to do that. Toyota has.

Two of the tools Toyota uses to teach problem solving are their suggestion program and quality circles. (I can hear the groan from here.) You say you've had a suggestion program for years that nobody ever contributes to. You say you did quality circles in the '80's but nothing panned out. Maybe it's time to look into these a little more because in 1999, 5,048 of those 7,800 team members at TMMK submitted 151,328 ideas for improvements and implemented nearly all of them. These ideas generated just under $41.5 million in savings and earned those team members $5.1 million in pay outs. The 266 Quality Circles (QC) that team members voluntarily participated in saved an additional $10.2 million. In most places, that's real money! Why does it work for Toyota but no one else? Because at Toyota, the primary purpose of both the suggestion program and the quality circles is to improve the people, not necessarily the processes.

When a team member has an idea, he or she shares it with the team leader, who serves as a coach and helper, rather than a taskmaster. The team leader helps the team member test the idea to see if it is feasible, or if it has enough merit to go through the suggestion system. If it does, together they complete the suggestion form, which is essentially built around the problem-solving process (identify the problem, gather information, develop courses of action, analyze the courses of action, decide which offers the best solution, implement the solution, and follow up.)  Simply by going through the process of completing the form, the team member learns.  Depending on the idea, the team member may even get to make a presentation to company leadership, creating another employee improvement or learning opportunity.

Team leaders and group leaders use the quality circle as a short-term team to solve particular problems.  These might be problems from a different area in the plant that the QC members haven't worked in.  Sometimes a different perspective helps solve a problem.  But again, the real focus is not on fixing the particular production problem, but rather to teach the team members how to function as a team and how to think critically through a problem situation.  The QCs have to report to management what they do, and the structure of their report, just as with the suggestion form, is built around the problem solving process.

The involvement of the team leaders and group leaders in these activities with the team members gains for Toyota many intangible benefits to supplement the cost savings I mentioned earlier.  These leaders (coaches, helpers, facilitators) create the climate that supports the team members' problem solving.  Their approach teaches basic communication skills that are essential for developing future leaders.  It also builds trust and confidence between labor and management.  It has created in the heart of Kentucky a highly intelligent, dedicated, and committed workforce for Toyota.  Employee turnover is less than 5%. They know they are taken care of. They are well paid, and when you ride through the plant, you can see their satisfaction on their faces and in the way the do their jobs. Toyota has so far managed to operate for nearly 50 years without a layoff. They are doing things right.

Maybe for your next Kaizen event or Six Sigma project, you ought to consider creating a real, employee-focused suggestion program. You might find that you are able to make the leap from 15 or 20 big events a year to 150,000 small events.

Summary Box:

- Lean is a system, not a program
- A lean system focuses on producing quality people, rather than quality products
- A lean system, as demonstrated by the Toyota Production System, designs work to help team members reach higher levels of learning (problem solving skills)
- A robust suggestion system is effective for developing problem solving skills on an individual level
- Quality circles are effective for developing problem solving skills at the team level
- The benefits of focusing on producing quality people include tangible improvements (cost savings) and intangible improvements (trust) for the company

Implementation Strategies:

- Read *"40 Years, 20 Million Ideas: The Toyota Suggestion System"* by Yuzo Yasuda, published originally by the Japan Management Association, Tokyo 1989. English edition by Productivity Press, Inc, 1991.

- Take your time. It took Toyota 9 years (1951 to 1960) to achieve just a 20% participation rate that generated 5,000 ideas, of which only 36% were implemented.
- Make it voluntary, but with the full support of management at all levels. Don’t require your suggestion program to generate x number of ideas a month. Don’t require your quality circles to show how much money they contribute to the bottom line. Use both instead to teach the problem solving process; suggestion program for individuals, quality circles for teams.
- Respond quickly to suggestions. The area manager should contact the team member before the end of the shift. Make the compensation independent of the potential cost savings ($10 to $1500 range depending on the idea.) All ideas are valuable. Some save money immediately, others may serve only to encourage other team members to continue submitting ideas.
- Stick to it. Toyota has kept their systems intact since 1951. Companies don’t have to jump from one “hot” program to the next. This will bring stability to your work environment. Improvement first requires stability.

## 2. ASSURE SEAMLESS INFORMATION FLOW

*"Provide processes for seamless and timely transfer of and access to pertinent information."*

**METRICS**

-- Commonality of databases
-- Information retrieval time
-- Information sharing between customers and suppliers

**ENABLING PRACTICES**

- Make processes and flows visible to all stakeholders
- Establish open and timely communications, among all stakeholders
- Link databases for key functions throughout the value chain
- Minimize documentation while ensuring necessary data traceability and availability

## 3. OPTIMIZE CAPABILITY AND UTILIZATION OF PEOPLE

*"Assure properly trained people are available when needed."*

### METRICS

-- Training hours / employee
-- Output / employee

### ENABLING PRACTICES

- Establish career and skill development programs for each employee
- Ensure maintenance, certification and upgrading of critical skills
- Analyze workforce capabilities and needs to provide for balance of breadth and depth of skills/knowledge
- Broaden jobs to facilitate the development of a flexible workforce

## 4. MAKE DECISIONS AT LOWEST POSSIBLE LEVEL

*"Design the organizational structure and management systems to accelerate and enhance decision making at the point of knowledge, application, and need."*

### METRICS

-- Number of organization levels

### ENABLING PRACTICES

- Establish multi-disciplinary teams organized around processes and products
- Delegate or share responsibility for decisions throughout the value chain
- Empower people to make decisions at the point of work
- Minimize hand-offs and approvals within and between line and support activities
- Provide environment and well-defined processes for expedited decision-making

## 5. IMPLEMENT INTEGRATED PRODUCT AND PROCESS DEVELOPMENT

*"Create products through an integrated team effort of people and organizations which are knowledgeable of and responsible for all phases of the product's life cycle from concept definition through development, production, deployment, operations and support, and final disposal."*

### METRICS

-- Number of engineering changes (change traffic) after initial design release
-- IPT continuity through development cycle
-- Total product development cycle time from concept to launch
-- Supplier involvement in IPTs

### ENABLING PRACTICES

- Use systems engineering approach in product design and development
- Establish clear sets of requirements and allocate these to affected elements of the product and processes
- Definitize risk management
- Incorporate design for manufacturing, test, maintenance and disposal in all engineering phases
- Design in capability for potential growth and adaptability
- Establish effective IPTs
- Involve all stakeholders early in the requirements definition, design and development process
- Use a disciplined and documented software development process
- Implement design to cost processes
- Maintain continuity of planning throughout the product development process

## 6. DEVELOP RELATIONSHIPS BASED ON MUTUAL TRUST AND COMMITMENT

*"Establish stable and on-going cooperative relationships within the extended enterprise, encompassing both customers and suppliers."*

### METRICS

-- $\frac{\text{Number of strategic alliances}}{\text{total number of direct suppliers}}$

-- Number of projects with customers on IPTs

-- Percent of procurement dollars purchased under long-term supplier agreements

-- Number of years of relationship with suppliers

-- Existence of formal communications programs

### ENABLING PRACTICES

- Build stable and cooperative relationships internally and externally
- Establish labor-management partnerships
- Strive for continued employment or employability of the workforce
- Provide for mutual sharing of benefits from implementation of lean practices
- Establish common objectives among all stakeholders

## 7. CONTINUOUSLY FOCUS ON THE CUSTOMER

*“Proactively understand and respond to the needs of the internal and external customers.”*

**METRICS**

-- Customer access to supplier information
-- Percent of projects with customers on IPTs
-- On time delivery from source to point of use

**ENABLING PRACTICES**

- Provide for continuous information flow and feedback with stakeholders
- Optimize the contract process to be flexible to learning and changing requirements
- Create and maintain relationships with customers in requirements generation, product design, development and solution-based problem solving

## 8. PROMOTE LEAN LEADERSHIP AT ALL LEVELS

*“Align and involve all stakeholders to achieve the enterprise’s lean vision.”*

**METRICS**

-- Lean metrics at all levels

**ENABLING PRACTICES**

- Flow-down lean principles, practices and metrics to all organizational levels
- Instill individual ownership throughout the workforce in all products and services that are provided
- Assure consistency of enterprise strategy with lean principles and practices
- Involve union leadership in promoting and implementing lean practices

## 9. MAINTAIN CHALLENGE OF EXISTING PROCESSES

*"Ensure a culture and systems that use quantitative measurement and analysis to continuously improve processes."*

### METRICS

-- Number of repeat problems
-- Customer assistance to suppliers

### ENABLING PRACTICES

- Establish structured processes for generating, evaluating and implementing improvements at all levels
- Fix problems systematically using data and root cause analysis
- Utilize cost accounting/management systems to establish the discrete cost of individual parts and activities
- Set jointly-established targets for continuous improvement at all levels and in all phases of the product life cycle
- Incentivize initiatives for beneficial, innovative practices

## 10. NURTURE A LEARNING ENVIRONMENT

*"Provide for the development and growth of both organizations' and individuals' support of attaining lean enterprise goals."*

### METRICS

-- Training hours / employee
-- Use of "lessons learned" system
-- Provision of supplier training programs

### ENABLING PRACTICES

- Capture, communicate and apply experience-generated learning
- Perform benchmarking
- Provide for interchange of knowledge from and within the supplier network

## 11. ENSURE PROCESS CAPABILITY AND MATURATION

*"Establish and maintain processes capable of consistently designing and producing the key characteristics of the product or service."*

**METRICS**

-- Cpk
-- Scrap, rework and repair as percent of cost
-- Software productivity
-- Number of suppliers certified
-- Engineering changes (change traffic)
-- Lean practices adoption

**ENABLING PRACTICES**

- Define and control processes throughout the value chain
- Establish cost beneficial variability reduction practices in all phases of product life cycle
- Establish make/buy as a strategic decision

## 12. MAXIMIZE STABILITY IN A CHANGING ENVIRONMENT

*"Establish strategies to maintain program stability in a changing customer driven environment."*

**METRICS**

-- Schedule changes
-- Number of baseline changes / year
-- Number of program restructures
-- Procurement quantity changes
-- Program administration continuity

**ENABLING PRACTICES**

- Level demand to enable continuous flow
- Use multi-year contracting wherever possible
- Minimize cycle-time to limit susceptibility to externally imposed changes
- Structure programs to absorb changes with minimal impact
- Establish incremental product performance objectives where possible
- Program high risk developments off critical paths and/or provide alternatives

The Machine that Changed the World
by James P. Womack, Daniel T. Jones, and Daniel Roos
**1990; Harper Perennial, 1991**